Restoration of Hetch Hetchy Valley and San Francisco's Water Supply

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Q: After restoration, where will San Francisco gets is water?

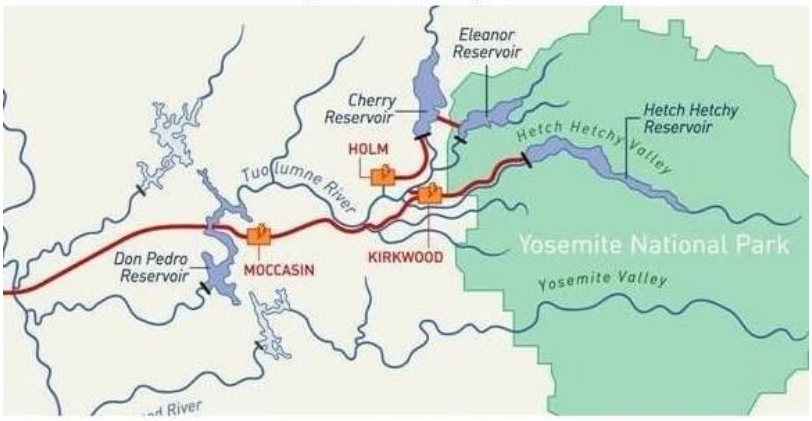
A: From the Tuolumne River, just as it does now.

Summary

The San Francisco regional water system currently receives 85% of its supply from the Tuolumne River watershed. San Francisco stores its Tuolumne River supplies in four reservoirs - Hetch Hetchy, Cherry, Eleanor and Don Pedro. Hetch Hetchy and Eleanor Reservoir lie within Yosemite National Park, while Cherry and Don Pedro Reservoirs are outside the park. Figure 1 shows San Francisco's facilities in the Tuolumne watershed.

With modifications to pipelines in the Tuolumne watershed, restoration could occur with San Francisco being able to retain almost all its Tuolumne derived supplies. Only modest new supplies would be required to ensure no loss in water system reliability.[1]

Figure 1: Tuolumne River components of San Francisco's regional water system



Hetch Hetchy Reservoir accounts for only about 25% of San Francisco's storage in the Tuolumne River watershed.

This report addresses only the most commonly asked question by restoration skeptics: Where would the water come from? Restoration would also require increased water treatment costs and replacement of about 350 gigawatt-hours per year of hydropower production – issues not addressed herein.

This approach would allow full deliveries of Tuolumne supplies in most years, but in the driest one out of five years there would be a shortage of about 60,000 acre-feet – about 20% of the San Francisco Regional Water System's overall system supply.

While a plethora of specific options for replacing 60,000 acre-feet of water in dry years is available, no particular alternative is singled out herein. The identification, development and implementation of a particular alternative is the purview of San Francisco and its Bay Area customers as they are best suited, given proper incentive, to determine what is the best option for their system.

Nevertheless, any of the following four specific options could comprise a specific water supply alternative (with sufficient incentives for the cooperating districts):

- Enlarge Los Vaqueros Reservoir in Contra Costa County by 360,000 acre-feet or more and improve interconnections between the Contra Costa Water District, the East Bay Municipal Utility District and the San Francisco Regional Water System.
- Bank 360,000 acre-feet or more of groundwater with the Semitropic Water Storage District in Kern County, and connect San Francisco's aqueduct to the California Aqueduct.
- Purchase 60,000 acre-feet of supply in dry years from the Turlock, Modesto or Oakdale Irrigation Districts. The Districts could use the funds received to recharge and improve the management of local groundwater supplies.
- Recycle 60,000 acre-feet of supply annually at Bay Area wastewater plants.

Note that over the last 25 years other California urban agencies have developed more than 1,000,000 acre-feet of dry year supply – more than 18 times the amount of water required to restore Hetch Hetchy Valley - through a combination of surface storage, groundwater storage, water purchases and water recycling programs[2]. Most of this supply has been developed in response to requirements that these agencies improve the environmental performance of their water systems. *Presently, San Francisco simply lacks the political will to make the system modifications necessary to return the Hetch Hetchy Valley in Yosemite National Park to the American people.*

Water supply effects of other aquatic restoration programs in California

Water development has been critically important in semi-arid California, for supporting both its growing population and its world-class agricultural industry. In some instances, however, the impact on aquatic environments has been found to be unacceptable and significant modifications to the operations of some water delivery systems have been required.

Since 1992, California water agencies have modified their water systems to better protect some of the state's most renowned rivers and wetlands, as well as the fish and wildlife they support. None of these changes have been easy and some have been particularly controversial, but in large part improvements in the use, storage and delivery of water have been beneficial to California's natural heritage.

Table 1 below provides a list of five distinct instances in which water has been redistributed back to the environment, and compares the amounts of these supplies with the amount that would be required to restore Hetch Hetchy Valley in Yosemite National Park.

Water agencies throughout California have made significant modifications to their systems in order to improve environmental performance with respect to California's rivers, wetlands and the Bay Delta. These volumes of rededicated water are far in excess of that which would be required to restore Hetch Hetchy Valley in Yosemite National Park.

Table 1: Annual Water Volumes Rededicated for Environmental Uses Since 1992 (acre-feet)

Environmental Reoperation	Average of all years	Critically Dry Years
San Joaquin Valley Wetlands (1992): Water supply exported from the Delta redirected from agricultural use to wetlands for the benefit of waterfowl.	250,000	200,000
Mono Lake (1994): Water diversions to Los Angeles reduced in order to restore the water level of Mono Lake for the benefit of waterfowl.	46,000	30,000
Bay-Delta Accord (1994-1995): State Water Board ratifies agreement to improve springtime Delta outflow and protect estuarine fish. Deliveries of water exported from the Delta are reduced to San Joaquin Valley farms as well as to cities in northern and southern California.	316,000	430,000
Trinity River Restoration Plan (2000): Diversions from the Trinity River are reduced to improve salmon and steelhead populations, reducing water supplies delivered to Central Valley farms.	83,000	155,000
Delta Endangered Species Act rulings (2008): Regulations governing the flows of Old and Middle River in the Delta to protect salmon and Delta smelt result in reduced export deliveries to San Joaquin Valley farms as well as to cities in northern and southern California.	980,000	572,000
Hetch Hetchy Valley in Yosemite National Park (20XX): Proposal to restore this once iconic valley would diminish delivery of Tuolumne River water supplies to San Francisco Bay Area.	12,000	60,000

Since 1992, more than 1,500,000 acre-feet of water have been redirected for environmental purposes. Affected agencies have responded by developing new surface and groundwater storage, recycling water, investing in efficiency (especially drip irrigation), and participating in an increased number of market transactions.

San Francisco's water system as it exists today

It's important to realize that San Francisco's water system includes nine reservoirs - five in the Bay Area, and four in the Tuolumne watershed. The five Bay Area reservoirs principally hold runoff from local watersheds and provide about 15% of the total supply of San Francisco's system. The location and sizes of these reservoirs are shown in Figure 2 and Table 2 respectively.

Figure 2: San Francisco Regional Water System

San Francisco owns and operates three "upcountry" reservoirs in the Tuolumne watershed - Cherry, Eleanor and Hetch Hetchy. These facilities, along with several pipelines and powerhouses, were authorized by the federal Raker Act in 1913 – the one time in American history that a city was allowed to build significant infrastructure in a national park.

The fourth, and largest reservoir, is Don Pedro - owned and operated by the Turlock and Modesto Irrigation Districts. Don Pedro is almost 6 times as large as Hetch Hetchy Reservoir, and one third of its storage is dedicated to a water "bank" for San Francisco – a

Table 2: Principle Tuolumne River and SFPUC Reservoirs (acre-feet)

Bay Area	
Pilarcitos	3,000
San Andreas	19,000
San Antonio	51,000
Crystal Springs	69,000
Calaveras	97,000
Upper Tuolumne	
Eleanor	27,000
Cherry	273,000
Hetch Hetchy	360,000
Lower Tuolumne	
Don Pedro (SF Water Bank)	634,000
Don Pedro (MID/TID portion)	1,395,000
SFPUC Total	1,533,000

privilege for which San Francisco paid half the cost of Don Pedro's construction. San Francisco does not presently draw water directly from Don Pedro, nor is it permitted to do so under its "fourth agreement" with Turlock and Modesto, but the water bank provides functional storage as it allows San Francisco to divert river flows upstream that would otherwise belong to the districts.

Together the Bay Area and Tuolumne components of San Francisco's water system provide about 265,000,000 gallons of water per day. Roughly 1/3 of this water is delivered to customers within the City and County of San Francisco. The remaining two thirds is delivered to customers in San Mateo County and parts of Alameda and Santa Clara Counties.

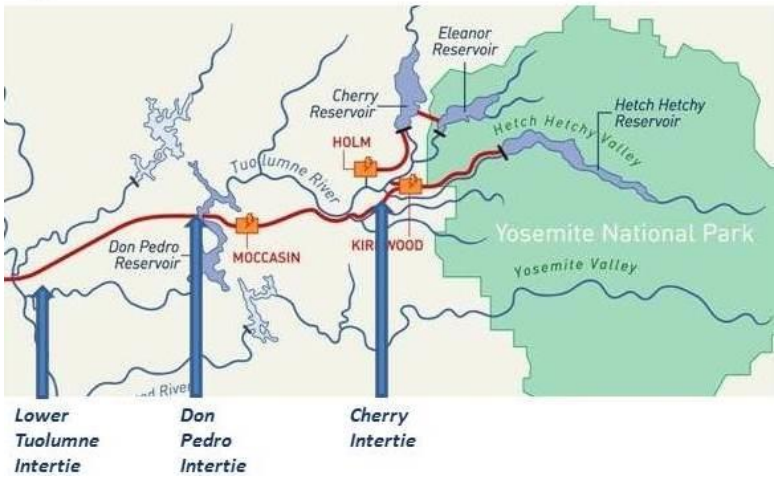
Some, but not all, restoration alternatives would involve San Francisco's direct use of its Don Pedro water bank – something not presently permitted by the Turlock and Modesto Irrigation Districts. It is Restore Hetch Hetchy's view that a restoration plan can be developed that provides the Districts' with assurances that their rights and water supplies will be protected if they allow San Francisco direct access to Don Pedro Reservoir on occasion, despite their current reluctance to do so.

Diverting Tuolumne Supplies without Hetch Hetchy Reservoir

First and foremost, San Francisco would continue diverting from the Tuolumne River into its Mountain Tunnel at Early Intake when there is sufficient river flow – typically in winter, spring and early summer. This is the present point where Tuolumne supplies are diverted below Hetch Hetchy Reservoir.

During the dry months of the year, San Francisco would divert water that is stored in either Don Pedro or Cherry Reservoirs. To make these diversions possible, one or more new interties from other Tuolumne River reservoirs to San Francisco's existing conveyance system are necessary. Potential interties are shown in Figure 3.

Figure 3: Potential new Tuolumne River interties



Cherry Intertie: San Francisco itself has considered building an intertie from Holm powerhouse below Cherry Reservoir to Early Intake. Such an interconnection would need

no cooperation from any other water agencies and would continue to provide high quality Sierra water supplies to the San Francisco Regional Water System.

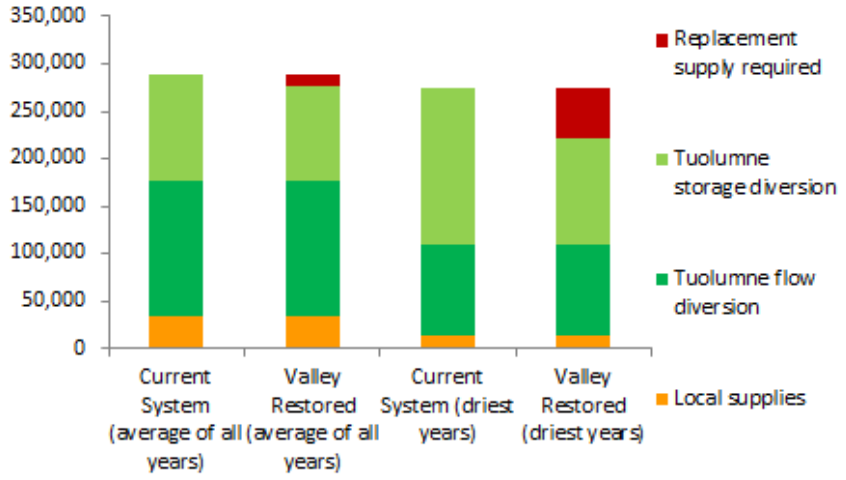
Don Pedro intertie - An intertie to the Don Pedro Reservoir would require cooperation with the Turlock and Modesto irrigation districts that own and operate the reservoir. Don Pedro water quality is also very good.

Lower Tuolumne River intertie – An intertie along the lower Tuolumne River could be constructed near its confluence with the San Joaquin River. Such an intertie would allow additional flows to remain within the Tuolumne River improving conditions for salmon and other fish between the confluence and upstream dams. San Francisco considered such an intertie as part of its Water System Improvement Plan but elected not to construct it.

There have been two comprehensive water system simulation modeling efforts to show how the Tuolumne system would perform without the O'Shaughnessy Dam/Hetch Hetchy Reservoir - one by UC Davis in 2003 using the Calvin Model and one by the Environmental Defense Fund in 2004-2005 using the TREWSSIM model. The two models showed very similar results.

In most years no additional water supply would be required. But in the driest years San Francisco's water system would be about 20% short in supply. Approximately 60,000 acre-feet per year in additional supply would be required to make up the shortfall.

Figure 4: Delivering Water without Hetch Hetchy Reservoir
(acre-feet per year)



Without Hetch Hetchy Reservoir, only modest additional supplies (shown in red) would be required in dry years

Connections to and Cooperation with Other Water Systems

Many of the best water supply opportunities for San Francisco and its Bay Area customers involve improved institutional and physical interconnection with other water agencies. Cooperation between California's water districts has improved significantly in recent years.

Representatives of the Metropolitan Water District of Southern California have successfully negotiated transfer agreements in the Sacramento Valley where not long ago doors were literally slammed in their faces. East Bay Municipal Utility District and the Contra Costa Water District, two neighbors that for years did not cooperate, have installed new interconnections and negotiated agreements to use them. And most of the large urban water agencies in California are now banking groundwater in Kern County. This new level of cooperation among water agencies has expanded opportunities statewide for investing in reliable supplies, while simultaneously providing additional incentives for efficient use.

In addition to helping make restoration of Yosemite's Hetch Hetchy Valley possible improving interconnections would improve water supply reliability in the event of drought or infrastructure

But with a few limited exceptions, San Francisco's system remains isolated from the rest. San Francisco has chosen to keep its Tuolumne River-based supply system separate from others in the state, and has explored a limited set of water supply options that could increase reliability in their service territory. Finding ways to work better with other agencies is an important step for San Francisco, regardless of the issue of restoring Yosemite's Hetch Hetchy Valley. But any restoration plan is likely to be far more cost effective if San Francisco is better connected with other agencies in the Bay Area and beyond. Such interconnections would provide the opportunity to increase reliability and efficiency in other parts of the state as well.

Many of the supply alternatives described below rely on improved connections between water agencies. Principal Bay Area and other regional water districts and existing major water conveyance facilities are shown in Figure 5.

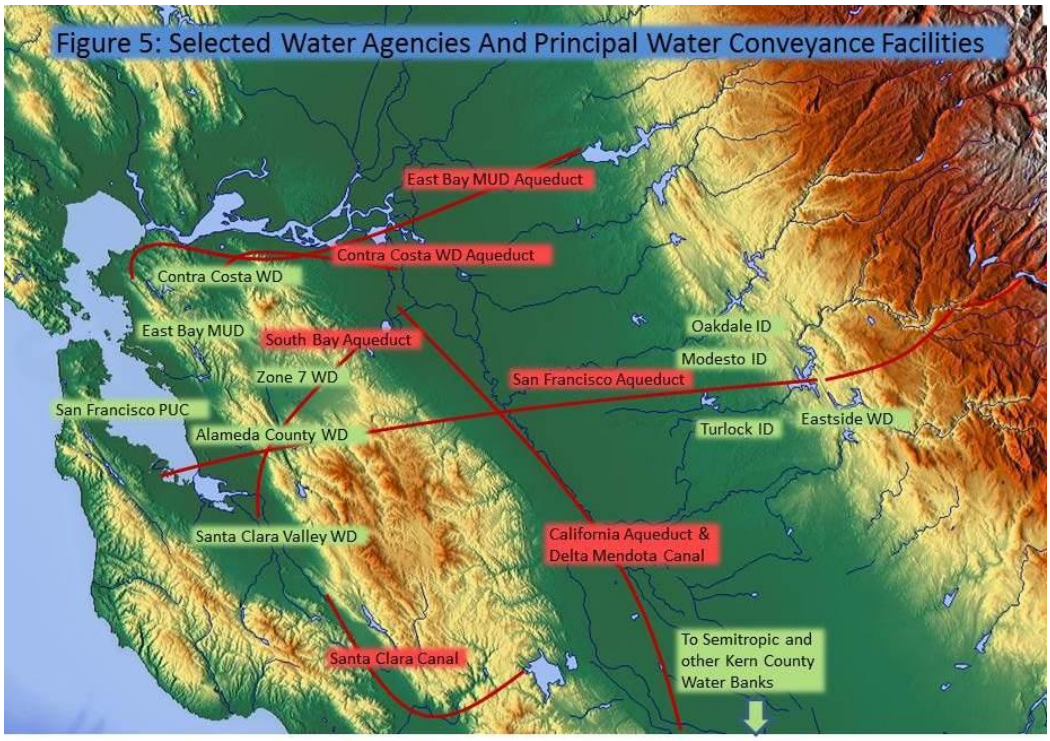


Figure 5: Selected Water Agencies And Principal Water Conveyance Facilities

New surface storage

Perhaps the most intuitive way replenish loss of water supply while restoring Hetch Hetchy Valley is to replace the surface storage that would be lost with additional surface storage elsewhere. Most recent surface storage projects in California are "offstream" - these are reservoirs that are not located on a major streambed but are supplied by a pipeline or aqueduct. There are three major reasons for this recent trend toward building reservoirs offstream: (1) most good on-stream sites are already developed, (2) on-stream sites tend to inflict more environmental damage – to the canyon itself and/or downstream aquatic habitat, and (3) the storage can often be constructed closer to its customers, diminishing the likelihood of a serious pipeline outage.

Surface Storage Opportunities for San Francisco

Los Vaqueros Reservoir: Originally constructed in 1998 and expanded to 160,000 acre-feet in 2010, the Los Vaqueros Reservoir in Contra Costa County could be expanded to hold as much as 1,000,000 acre-feet - enough additional storage to hold Hetch Hetchy Reservoir more than two times over. An expanded Los Vaqueros could benefit San Francisco through existing conveyance via its interconnection with East Bay MUD. A substantial increase in Los Vaqueros capacity however would likely warrant additional interconnections within the Bay Area.

Pacheco Reservoir: Operated by the Santa Clara Valley Water District, Pacheco Reservoir has been proposed for expansion. It could be integrated into San Francisco system easily, as Santa Clara and San Francisco share customers in Alameda and Santa Clara counties.

Corral Hollow Reservoir: Just south of Livermore, the Corral Hollow site could hold more than 1,000,000 acre-feet - or three times the volume of Hetch Hetchy Reservoir. It has been considered both by the Department of Water Resources and San Francisco, but not deemed cost effective during previous assessments. Its location, adjacent to the California Aqueduct, San Francisco's Hetch Hetchy Aqueduct, and the South Bay Aqueduct, make it an investment that could be shared by almost any water agency in California. The area currently includes an off-road vehicle Park and a small piece of Lawrence Livermore National Laboratory which would have to be moved.

Calaveras Reservoir: San Francisco's 97,000 acre-feet Calaveras Reservoir is currently being rebuilt as part of its Water Supply Improvement Program after having been declared unsafe. Originally San Francisco proposed to rebuild it with a significant increase in size, but subsequently opted to rebuild to its current size with the possibility for limited expansion at a later date.

Recent surface storage projects in California

Table 3 provides examples of recently built surface storage in California. These projects have helped urban water agencies in northern and southern California improve the reliability of their supply while reducing the impact of their water diversions from the Bay Delta.

Table 3 – Recently constructed surface storage	
Project	Utilities
Los Vaqueros Reservoir	Built in 1998 by Contra Costa Water District to a capacity of 98,000 acre-feet, expanded in 2010 to 160,000 acre-feet.
Diamond Valley Reservoir	Built in 2003 by Metropolitan Water District of Southern – 810,000 acre-feet.
San Vicente Reservoir	San Diego – presently being enlarged from 90,000 acre-feet to 242,000 acre-feet.

New groundwater storage

Opportunities for groundwater development have increased as agricultural and urban agencies (as well as investors) have realized that many of the groundwater basins that were depleted throughout the 20th century can be refilled and managed. The technology to evaluate, develop and manage groundwater has improved to the point where most new storage is now underground. Some communities have invested in their own groundwater, and others have entered into banking contracts with agencies hundreds of miles away.

The water supply "yield" of surface and groundwater storage projects depends on a number of factors including hydrology, demand patterns and what other resources are available. Aquifers are generally conveyance-limited, i.e. there are limitations to how quickly water can be put in or taken out. When developed and managed conjunctively with surface reservoirs and other supplies, however, groundwater projects provide the same water supply benefits as surface storage projects.

Groundwater Storage Opportunities for San Francisco

Kern County Groundwater Banking: The Semitropic and Antelope Valley water banks are currently looking for investors for up to 800,000 acre-feet in storage.[3] Accessing these water banks in Kern County would require San Francisco to connect its Hetch Hetchy aqueduct to the California Aqueduct, or to access supplies through the Santa Clara Valley Water District.

San Joaquin Valley Groundwater Banking: San Francisco has investigated groundwater banking opportunities in the San Joaquin Valley, as well as in its own service territory. [4] For example, San Francisco assessed banking groundwater in the Eastside Water District (East of Turlock) as ideal in some respects, but "institutionally complex" – i.e. it would require cooperation with both the Turlock Irrigation District and the Eastside Water District.

Bay Area Groundwater Capacity: San Francisco is making improvements in its local groundwater management. It has developed a project to blend groundwater with surface supplies in the west side of the city, and it has worked with Daly City, Colma and Millbrae to manage the basin southwest of San Francisco for improved reliability in dry years.

But many parts of San Francisco's service territory no longer manage their aquifers and therefore have an inordinate reliance on imported water. These cities include Hayward and

Palo Alto, whose Urban Water Management Plans explicitly state that they have given up their local groundwater in spite of language in the 1913 Raker Act that requires them to maintain local supplies.[5]

Recent groundwater storage projects for urban agencies in California

Urban agencies listed below, among others, have found investing in groundwater storage, locally and through banking agreements, to be cost effective.

Table 4: Recently Developed Groundwater Storage by California Urban Water Agencies

Project	Utilities
Semitropic Water Storage District	Alameda County Water District – 150,000 acre-feet Metropolitan Water District – 350,000 acre-feet Santa Clara Valley Water District – 350,000 acre-feet Zone 7 - 65,000 acre-feet
Kern Delta Water Bank	Metropolitan Water District of Southern California - 350,000 acre-feet
Local Projects (Long Beach, Chino, Orange County, Compton etc.)	Metropolitan Water District of Southern California – 212,000 acre-feet
Arvin Edison Water Bank	Metropolitan Water District of Southern California – 350,000 acre-feet

Transfers

Water transfers, the sale of water from one agency to another, have been commonplace for several decades. Application of market forces in the water business has been and continues to be complex – sometimes but not always for good reason. In many agricultural regions, the cost of water is $10 or less per acre-foot, less than 1% of the cost in cities. Even accounting for the cost of transport and treatment, city dwellers pay a far higher price. Limited volumes of water transfers from the agricultural sector to the urban sector have helped to mitigate water shortages in California's cities while providing farms important capital for improving the productivity of irrigation systems.

Still, many agricultural areas decline to sell any water across county lines, preferring instead "to grow our own community". Recent controversy over Modesto's proposed sale to San Francisco is a case in point. Metropolitan's success story in many areas of California lies in its patient development of relationships throughout California and negotiating agreements to the mutual benefit of both parties

Transfers available to San Francisco

With an intertie to Don Pedro Reservoir or to the lower Tuolumne River, San Francisco could execute water transfers with the Turlock, Modesto, and Oakdale Irrigation Districts.

With an intertie to the California Aqueduct, San Francisco could execute water transfers with almost any agency in the state.

Recent water transfers for urban agencies in southern California

Southern California water agencies have successfully negotiated a series of agreements with agricultural agencies throughout California to help improve their water supply reliability.

Table 5: Water Transfers to California Urban Water Agencies

Utility	Transactions
Metropolitan Water District of Southern California (on behalf of all customers)	Water transfers to MWD through State Water Project and Colorado Aqueduct – 331,000 acre-feet per year (average 2008-2010, average cost $218 per acre-foot)
San Diego County Water Authority	Water transfers through Colorado Aqueduct - 124,000 acre-feet per year (average 2008-2010, average cost $688 per acre-foot)
MWD customers (other than San Diego)	Water transfers through the State Water Project - 77,000 acre-feet per year (average 2008-2010, average cost $267 per acre-foot)

Recycling Trends and Opportunities

Perhaps the most recent trend, and a potential game changer for urban water supplies in California as well as other arid and semiarid parts of the world, is wastewater recycling.

Until recently, recycled wastewater has mostly been used for irrigation and in industry – not for potable uses. The challenge has been that the application of these recycled supplies requires two sets of pipes - one for potable water and one (sometimes colored purple) for recycled supplies.

Improvements in water treatment, however, especially microfiltration (often described as reverse osmosis), are encouraging the water industry to consider and move forward with proposals for the potable reuse of recycled supplies. Orange County water district, for example, recycles wastewater, uses it to replenish groundwater supplies, and eventually delivers the recycled water to its customers - something known as indirect potable reuse.

Others agencies are going one step further, and are putting recycled supplies directly back into the potable system - i.e. direct potable reuse. This application was successful in Singapore after government officials and celebrities drank the "NEWater" on television as part of a public relations campaign. The San Diego County Water Authority and the Santa Clara Valley Water District are currently pursuing such programs.

Opportunities in San Francisco and its service area

San Francisco and its retail customers currently produce very little recycled water, and plans to do more over the next 25 years are limited. The potential adoption of potable reuse technologies, whether direct or indirect, would provide these and other cities with perhaps the most reliable source of additional supply. San Diego recently estimated the cost to be about $2100 per acre-foot – without factoring in the avoided wastewater costs of $1000 per acre-foot.[6]

A few of the larger current recycling programs in Southern California are listed below in table 6.

Table 6: Water Recycling Examples in California

Utility	Program or Project
Santa Clara Valley Water District	Will double production of recycled water by 2035 (from 14,000 acre-feet per year to 29,000 acre-feet per year.
Orange County Water District	The OCWD provides recycled water to the Municipal Water Districts of Orange County, which currently use 40,000 acre-feet of recycled water per year and expect to increase the amount to 60,000 acre-feet per year by 2035.
West Basin	Currently recycles 30,000 acre-feet per year - plans to expand to 70,000 acre-feet per year by 2035.
Los Angeles	Currently recycles 5,000 acre-feet per year - plans to expand to 59,000 acre-feet per year by 2035.
San Diego	Currently recycles 27,931 acre-feet per year - plans to expand to 49,998 acre-feet per year by 2035.

Other alternatives

Storage, above or below ground, water transfers and recycling opportunities are some of the water supply replacement opportunities that could be implemented to make up for the loss of Hetch Hetchy Reservoir.

There are other possibilities as well. As water experts around the state are fond of saying, "there is no silver bullet that will solve California's water needs". An integrated approach should be pursued that encompasses the elements discussed above, and perhaps include the following as well:

Conservation – While San Francisco's per capita use is among the lowest in the state, some of its customers do use significantly higher amounts. There is always room for improvement.

Storm water - Bay Area cities could follow the lead of some Southern California communities which have improved storm water harvesting by installing the infrastructure to allow it to percolate into groundwater basins.

Gray water – Homes and businesses are installing gray water systems, essentially applying recycled water from some household uses (other than toilets and kitchen sinks) for irrigation.

Desalination – Desalination is expensive technology, and especially expensive if done right to minimize energy, beach and ocean impacts. Desalination is on the increase worldwide, however, and may yet play a significant role in California's future.

Conclusion

The fundamental question of replacing water supply to accommodate the restoration of Hetch Hetchy Valley in Yosemite National Park is eminently solvable. Cities throughout California have done far more.

But there is presently no apparent willingness on the part of city officials to consider restoration, even though San Francisco stands out as being the only city in the United States which has destroyed a national park for its own benefit.

The viable alternatives described in this report will likely remain unexplored by San Francisco until such time as it is provided the incentives, positive or otherwise, to pursue them.

Artist's rendition of a 21st century restored Hetch Hetchy Valley in Yosemite (Levelpar)

[1] There have been several simulation model studies that demonstrate how San Francisco's system could operate without the O'Shaughnessy Dam and Hetch Hetchy Reservoir. See Paradise Regained (Environmental Defense Fund, 2004), Tuolumne Watershed Diversions without Hetch Hetchy Reservoir: Comparison of Interties to Cherry and Don Pedro Reservoirs (Environmental Defense Fund, 2005), and REASSEMBLING HETCH HETCHY: WATER SUPPLY WITHOUT O'SHAUGHNESSY DAM, (Lund and Null, 2006). While all results are similar, for the purposes herein, results from EDF's "Tuolumne Watershed Diversions without Hetch Hetchy Reservoir" document are used.

[2] Replacing the water supply that would be lost can either be provided by developing 360,000 acre-feet of storage OR 60,000 acre-feet of supply in dry years. The storage, transfer and recycling programs described in this document total more than 18 times these values.

[3] See http://www.semitropic.com/BankingPartners.htm.

[4] See Paradise Regained, page A – 2 (Environmental Defense Fund 2004) and City and County of San Francisco Hetch Hetchy Water and Power, Reconnaissance Evaluation of Alternative Sites for Groundwater Banking, Bookman-Edmonston Engineering Inc., and Luhdorff and Scalmanini, Consulting Engineers, unpublished work July 1993

[5] Section 9(h) of the Raker Act reads "That the said grantee shall not divert beyond the limits of the San Joaquin Valley and more of the waters from the Tuolumne watershed than, together with the waters which it now has or may hereafter acquire, shall be necessary for its beneficial use for domestic and other municipal purposes."

[6] See Water Purification Demonstration Project, *Project Report (Final Draft),* C I T Y O F S AN D I EGO, MARCH 2013